



Europäisches Patentamt  
European Patent Office  
Office européen des brevets



Publication number: **0 242 199 B1**

12

## EUROPEAN PATENT SPECIFICATION

45 Date of publication of patent specification: **16.10.91** 51 Int. Cl.<sup>5</sup>: **C01B 3/38, B01J 8/06**

21 Application number: **87303307.0**

22 Date of filing: **15.04.87**

54 Process and apparatus for the production of synthesis gas.

30 Priority: **15.04.86 GB 8609099**

43 Date of publication of application:  
**21.10.87 Bulletin 87/43**

45 Publication of the grant of the patent:  
**16.10.91 Bulletin 91/42**

84 Designated Contracting States:  
**BE DE FR GB IT NL**

56 References cited:  
**GB-A- 2 153 382**  
**GB-A- 2 179 366**  
**US-A- 3 450 514**

**CHEMICAL ABSTRACTS, vol. 103, no. 24, December 1985, page 144, abstract no. 198441f, Columbus, Ohio, US;**

73 Proprietor: **The British Petroleum Company p.l.c.**  
**Britannic House Moor Lane**  
**London EC2Y 9BU(GB)**

72 Inventor: **Egglestone, Frederick**  
**The British Petroleum Co. p.l.c. Britannic House**  
**Moor Lane London EC2Y 9BU(GB)**

74 Representative: **Richardson, Derek et al**  
**BP INTERNATIONAL LIMITED Patents & Agreements Division**  
**Chertsey Road**  
**Sunbury-on-Thames Middlesex TW16 7LN(GB)**

Note: Within nine months from the publication of the mention of the grant of the European patent, any person may give notice to the European Patent Office of opposition to the European patent granted. Notice of opposition shall be filed in a written reasoned statement. It shall not be deemed to have been filed until the opposition fee has been paid (Art. 99(1) European patent convention).

## Description

The present invention relates to a process and apparatus for the production of synthesis gas.

Synthesis gas is the name generally given to a gaseous mixture principally comprising carbon monoxide and hydrogen, but also possibly containing carbon dioxide and minor amounts of methane and nitrogen. It is used, or is potentially useful, as feedstock in a variety of large-scale chemical processes, for example the production of methanol, the production of gasoline boiling range hydrocarbons by the Fischer-Tropsch process and the production of ammonia.

Processes for the production of synthesis gas are well known and generally comprise steam reforming, autothermal reforming, non-catalytic partial oxidation of light hydrocarbons or non-catalytic partial oxidation of any hydrocarbons. Of these methods, steam reforming is generally used to produce synthesis gas for conversion into ammonia or methanol.

Modifications of the simple steam reforming processes have been proposed. In particular, there have been suggestions for improving the energy efficiency of such processes in which the heat available from a secondary reforming step is utilised for other purposes within the synthesis gas production process. For example, processes are described in GB-A-1550754, US-A-4479925 and GB-A-2153382 in which heat from a secondary reformer is used to provide heat to a primary reformer.

GB-A-1,550,754 describes a process for the steam reforming of hydrocarbons by the sequence of primary and secondary reforming, which comprises the steps of

(a) heating a first mixture of hydrocarbons in the presence of steam reforming catalyst to form a first partially reformed effluent,

(b) heating a second mixture of hydrocarbon feed and steam to conditions at which primary reforming occurs by indirect heat exchange with the process gas as hereinafter defined and reforming said hydrocarbons in the presence of a steam reforming catalyst to form a second partially reformed effluent,

(c) introducing said first and second partially reformed effluents to a secondary reformer to carry out said secondary reforming in the presence of oxygen and forming a secondary reforming effluent, and passing said secondary reforming effluent as the process gas in indirect heat exchange with said second mixture of hydrocarbon feed as set forth in (b) above.

The primary reformer which is heated by the effluent from the secondary reformer is a shell and tube heat exchanger-reactor.

US-A-4479925 discloses a process for producing ammonia synthesis gas in a reactor-exchanger primary reformer followed by an autothermal secondary reformer in which the primary reformer is heated by synthesis gas from the secondary reformer. The primary and secondary reformers are separate units, the primary unit being a shell and tube heat exchanger-reactor.

GB-A-2153382 discloses an autothermal process for producing a synthesis gas in which a mixture of steam and hydrocarbon feed gas is reacted by passing the mixture through a catalyst in counter-current flow to the combustion reaction effluent of the process, to cool the reaction effluent and to provide heat for the reaction of the steam-hydrocarbon feed gas mixture and introducing oxygen or oxygen-enriched air to form said combustion reaction effluent. The patent application also discloses a reactor for carrying out the process which essentially comprises a shell and tube heat exchanger-reactor as the primary reformer.

The present invention provides a process and apparatus for the production of synthesis gas by the sequence of primary and secondary reforming in which the available heat of the effluent from the secondary reforming is efficiently used to provide heat for the primary reforming. The apparatus has the advantage that it is mechanically relatively simple. The apparatus is of a modular design which allows the heat requirement to be easily changed and which also provides operational and maintenance advantages.

Thus according to the present invention there is provided apparatus suitable for use in the production of synthesis gas from hydrocarbons which comprises a primary reforming zone in which a hydrocarbon - containing gas and steam are partially reformed in the presence of a primary reforming catalyst to produce a primary reformer effluent and a secondary reforming zone in which the primary reformer effluent and an oxygen - containing gas are reacted in the presence of a secondary reforming catalyst to produce a secondary reformer effluent characterised in that (1) the primary reforming zone comprises a plurality of double pipe heat exchanger - reactors arranged peripherally about the circumference of a single reforming zone and close coupled thereto and (2) each double pipe heat exchanger-reactor is (a) adapted to contain the primary reforming catalyst in either its central core or annulus and (b) provided with at least one inlet for introducing steam and hydrocarbon-containing gas into whichever of the central core or annulus contains the primary reforming catalyst, an outlet for conveying the primary reformer effluent to the secondary reforming zone and an inlet for introducing the secondary reformer effluent into whichever of the central core

or annulus does not contain the primary steam reforming catalyst countercurrently to the steam and hydrocarbon-containing gas and exit from the same for removing the secondary reformer effluent from the apparatus.

If the primary steam reforming catalyst is positioned in the inner core of the double-pipe heat exchanger-reactor, the outer pipe tends to be subjected to a higher temperature and would have to have a relatively thick wall unless insulated. Preferably, therefore, in operation the primary steam reforming catalyst of the primary reforming zone is positioned in the annulus of the (or each) double-pipe heat exchanger-reactor(s).

In a preferred embodiment, a plurality of double-pipe heat exchanger-reactors, typically 2 to 10, are associated with a single secondary reforming zone. Thus, for example, apparatus according to the present invention may comprise 7 secondary reforming zones each of which is associated with 6 double-pipe heat exchanger-reactors i.e. the total number of double-pipe heat exchanger-reactors is 42.

Suitably, the apparatus according to the present invention may be constructed as a single unit in order to reduce piping and ancillary units.

In the present invention a plurality of double-pipe heat exchanger-reactors are arranged peripherally about the circumference of a single secondary reforming zone and are close-coupled thereto by, for example, interconnecting pipes. Typically, the secondary reforming zone may be of about 4m diameter and may have about 12 double-pipe heat exchanger-reactors arranged around the periphery thereof. Advantages of this arrangement are that it is more compact, i.e. it occupies a smaller area, and it facilitates the removal of one or more exchanger-reactors for maintenance purposes without substantially affecting operation of the remaining exchanger-reactors. Furthermore, it simplifies operation because it reduces the number of control operations, there being only one secondary reforming zone to control.

Whichever of the central core or annulus of each double-pipe heat exchanger-reactor is not being used for the primary reforming catalyst may be used to contain secondary reforming catalyst. Generally, the geometry of the double-pipe heat exchanger-reactor will not accommodate all of the secondary reforming catalyst, but by utilising the volume of the double-pipe heat exchanger-reactor, the volume of the second reforming reactor may be reduced.

The hydrocarbon-containing gas may suitably be any hydrocarbon capable of undergoing a steam reforming reaction, such as, for example, at least one hydrocarbon ranging from methane to naphthas having an end point of about 220°C,

including natural gas, ethane, propane and LPG. A preferred hydrocarbon-containing gas is natural gas. If required, the hydrocarbon-containing gas may first of all be desulphurised using technology known in the art and pressurised e.g. to about 40 to 80 atmospheres.

The feed to the primary reforming zone may optionally also include carbon dioxide.

The hydrocarbon-containing gas, steam and optionally carbon dioxide may suitably be preheated for example to a temperature in the range 400 to about 650°C before being introduced into the primary reforming zone. This preheating may suitably be accomplished at least in part by using waste heat from elsewhere in the process and/or by, for example a fired heater. At least the hydrocarbon-containing gas portion of the feed may then be passed through a catalyst guard bed for the purpose of removing impurities therein, for example sulphur, which may be undesirable downstream to, for example, the steam reforming catalyst.

The preheated feed is then passed to the primary reforming zone which comprises at least one double-pipe heat exchanger reactor containing a primary steam reforming catalyst in either the central core or, preferably, the annulus under steam reforming conditions.

Double-pipe heat exchangers are known and comprise two pipes one positioned inside the other, generally substantially concentrically. A packed stuffing box may be used to allow differential movement and removal of the inner pipe for cleaning or maintenance purposes.

The primary steam reforming catalyst used in the primary reforming zone may be any suitable catalyst including conventional steam reforming catalysts such as, for example, nickel, nickel oxide, chromia, molybdenum, or mixtures thereof, either supported or unsupported.

The primary reformer effluent which comprises unchanged hydrocarbon, carbon monoxide and hydrogen leaves the primary reforming zone at a temperature which is typically in the range from 650 to 950°C and is fed to the secondary reforming zone. The secondary reforming reactor contains secondary reforming catalyst which may be a catalyst of the same type as used in the primary reforming zone.

The oxygen-containing gas which is fed to the second reforming zone is suitably air, oxygen-enriched air or oxygen and is preferably preheated to a temperature in the range 100 to 300°C. The oxygen-containing gas is preferably oxygen if the synthesis gas is to be converted to methanol and air or oxygen-enriched air if it is to be converted to ammonia.

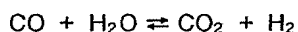
Steam, hydrocarbon-containing gas and/or car-

bon dioxide may also be fed to the second reforming zone. The hydrocarbon-containing gas, if used, is preferably obtained by dividing the feed to the primary reforming zone suitably after preheating.

The secondary reforming zone suitably takes the form of a refractory lined reactor operable under essentially adiabatic conditions. Part of the hydrocarbon is combusted in order to provide the heat required for reformation. Suitably, the temperature in the second reforming zone is maintained in the range from 900 to 1400°C, typically about 1200°C. The second reformer effluent is then passed to the primary reforming zone as the indirect heat exchange medium. The available heat of the second reformer effluent is used to provide heat for the endothermic reforming reactions by passing the second reformer effluent through one or more double-pipe heat exchanger-reactors counter-currently to the hydrocarbon-containing gas and steam feed mixture.

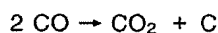
In an embodiment of the present invention, whichever of the central core or annulus of each double-pipe heat exchanger-reactor does not contain primary reforming catalyst may contain a carbon monoxide shift catalyst.

The carbon monoxide shift catalyst may suitably be either or both a conventional high temperature shift catalyst, for example Fe/Cr, or a steam reforming catalyst. An advantage of using this catalyst disposition is that, as the gas from the secondary reformer is cooled as it passes through the primary reforming zone, an extra exotherm is given out as the shift reaction:-



proceeds to the right hand side of the equation to maintain chemical equilibrium. This extra heat can be used to increase the gas outlet temperature, all other things being equal, thereby increasing the temperature driving force at the cooler end of the exchanger.

This enables operation with a lower steam consumption than would be possible without shift equilibrium. Another advantage of maintaining shift equilibrium as the gas is cooled is that the possible formation of carbon by the reaction:-



which can lead to blockage of the heat exchanger, is eliminated. For similar reasons, a shift catalyst may be included in downstream equipment, for example waste heat boilers.

The secondary reformer effluent is removed from the primary reforming zone at a temperature which may be for example in the range from 450 to 700°C and preferably cooled, thereby raising

some or all the steam required in the process. After cooling, carbon dioxide may be recovered from the effluent. Methods for removing carbon dioxide from such compositions are well known in the art. Any suitable method may be used, but it is preferred to use a physical solution process in order to avoid a demand for large quantities of steam for regeneration.

Carbon dioxide recovered from the secondary reformer effluent may be fed to the primary and/or secondary reforming zones, if required.

The process and apparatus according to the present invention can have a number of advantages over known processes and apparatus. The apparatus is relatively simple and can be manufactured using standard pipe sections. Thus the capital cost of the apparatus is low. Also the apparatus can be designed in the form of modules which allows the heat requirement and/or capacity of the process to be relatively easily changed by adding or removing double-pipe heat exchanger-reactors and/or secondary reforming reactors. This modular approach enables the apparatus to be easily transported and installed. It also allows individual double-pipe heat exchanger-reactors and/or secondary reactors to be shut-down for maintenance or replacement without having to shut-down the whole process. The use of double-pipe heat exchanger reactors also provides more uniform heating than shell and tube heat exchangers in which tubes at the edge of the tube bundle may be subjected to a different rate of heat exchange than tubes at the centre of the tube bundle.

The process and apparatus according to the present invention will now be further described with reference to the accompanying drawings in which;

Figure 1 is a schematic sectional view of an integral primary and secondary reformer.

Figure 2 is a schematic sectional view of another form of integral primary and secondary reformer.

Figure 3 is a schematic plan view of a plurality of double-pipe heat-exchanger reactors and a secondary reforming zone according to the present invention.

Figure 4 is a schematic elevation view of the arrangement of Figure 3.

Figure 5 is a flow diagram of a process according to the present invention

Figure 1 illustrates an integral primary and secondary reformer comprising a primary reforming zone 1 and a secondary reforming zone 2. The primary reforming zone 1 comprises a double-pipe heat exchanger-reactor having an inner pipe 3 and an outer pipe 4, the two pipes are substantially concentric. A primary reforming catalyst 5 is packed into the annulus 6 formed between the inner pipe 3 and outer pipe 4 which catalyst is

supported by packing 7. The feed for the primary reforming zone enters through inlet 8 and the primary reformer effluent leaves through outlet 9. Thus the feed passes along the length of the annulus 6 of the double-pipe heat exchanger-reactor. A packed gland 10 is provided to permit relative movement between the inner pipe 3 and outer pipe 4. The primary reforming zone is also provided with an access port 11. The secondary reforming zone 2 comprises a reactor, lined with a refractory material 19, attached to the primary reforming zone 1 at the opposite end to the feed inlet 8. Pipe 12 conveys the primary reformer effluent from the primary reforming zone 1 to the inlet 13 of the secondary reforming zone 2. Oxygen-containing gas and optionally steam, hydrocarbon-containing gas and/or carbon dioxide can be introduced via inlet 14. It will be appreciated that inlet 14 may be replaced by a number of separate inlets. The secondary reformer effluent leaves the secondary reforming zone 2 via outlet 15 which is connected to the inner core 16 of the primary reforming zone 1. The secondary reforming catalyst is shown as being contained in the secondary reforming zone 2 and also in the inner core 16 of the primary reforming zone.

The secondary reformer effluent passes along the length of the central core 16 of the primary reforming zone 1, countercurrently to the primary reformer feed, and leaves through outlet 18.

The pipes 3,4 of the double-pipe heat exchanger-reactor may be of any suitable size. For example in an embodiment of the present invention, the inner pipe 3 may have a nominal bore of 6 inches (152 mm) and the outer pipe 4 may have a nominal bore of 10 inches (254 mm). In another embodiment the inner pipe 3 may have a nominal bore of 8 inches (203 mm) and the outer pipe may have a nominal bore of 12 inches (305 mm).

The inner wall of the outer pipe 4 may be insulated e.g. with a refractory material in order to reduce heat loss. Insulating the inner wall of the outer pipe 4 may also allow a lower specification, lower cost material to be used for the pipe wall.

Since the temperatures to which the material of the pipes 3,4 will be exposed will be different at different positions along the length of the double-pipe heat exchanger-reactor, different materials can be used at different positions. For example, a metal suitable for use in a high temperature environment may be required adjacent the inlet for the secondary reformer effluent 15 whereas a lower specification, lower cost metal may be adequate adjacent the outlet 18 for the secondary reforming effluent.

Figure 2 illustrates another form of the apparatus in which the same reference numerals as used in Figure 1 are used to identify the same elements.

The second embodiment differs from the first embodiment in that in place of the pipe 12 for conveying the primary reformer effluent from the primary reforming zone 1 to the secondary reforming zone 2 a shell 20 is used which encloses the second reforming zone, this shell 20 is directly connected to the annulus 6 of the primary reforming zone and together with the secondary reforming zone forms an annulus for conveying the primary reforming effluent about the secondary reforming zone. The primary reforming effluent enters the secondary reforming zone via openings 21. In this embodiment, the secondary reforming catalyst 22 is shown as a bed which is wholly contained within the secondary reforming zone 2. The central core 16 of the double-pipe heat exchanger reactor may be packed with a carbon monoxide shift catalyst if desired.

Figure 3 illustrates an apparatus according to the invention in which the same reference numerals as used in Figure 1 are used to identify the same elements. In this embodiment a plurality of double-pipe heat exchanger-reactors 1 are peripherally arranged around the circumference of the secondary reforming zone 2, being close-coupled thereto by interconnecting pipes 12.

Figure 4 illustrates an elevation view of the arrangement of Figure 3 in which the same reference numerals as used in Figure 1 are used to identify the same elements. In this embodiment, instead of a single large diameter outlet 18 for the secondary reforming effluent there may be used a number of smaller diameter outlets. It will be readily appreciated that different arrangements of inlets 13 and 14 and pipes 12 are possible.

A process for producing synthesis gas according to the present invention is illustrated in Figure 5. In Figure 5, 32 represents a preheater, 33 represents a fired heater, 36 is a guard bed, 38 is an integrated primary and secondary reformer according to the present invention, 48 is a boiler for generating steam and 49 is a carbon dioxide recovery plant.

Desulphurised natural gas is fed through line 31 to the preheater 32 and thereafter through the fired heater 33. After exiting through line 34, it is passed through the guard bed 36 wherein poisons detrimental to the operation of the reforming catalysts are removed. A proportion of the natural gas is then passed through line 37 to the primary reforming zone of the integrated primary and secondary reformer 38. Carbon dioxide may also be fed to the primary reforming zone through line 40. Superheated steam is introduced via line 39.

The gas at exit from the primary reformer which may contain a considerable proportion of unconverted methane is passed through line 41 to the secondary reforming zone of the integrated

reformer 38. Also passed to the secondary reformer is a proportion of the preheated fresh natural gas through line 43, steam through line 44 and preheated oxygen through line 45. The facility also exists for adding carbon dioxide through line 51.

The gaseous stream exiting from the secondary reforming zone is passed as the indirect heating medium to the primary reforming zone of the integrated primary and secondary reformer 38 which may contain a catalyst to promote the shift reaction. In cooling and reacting it heats the primary reaction gases.

The secondary reformer effluent is then passed out of the primary reforming zone through line 47 and is cooled in the boilers 48. The steam raised thereby can be used in the process. Carbon dioxide can be recovered from the cooled gas stream in the carbon dioxide removal plant 49 using conventional technology. Recovered carbon dioxide can be recycled through line 50 to the reformer 38, optionally via a gas compressor.

The heat available from the secondary effluent may not be sufficient for all of the primary reforming. Additional primary reformer effluent may therefore be provided by a conventional radiant steam reforming furnace (not shown). Additional heat may be provided to the primary reforming zone of the apparatus according to the present invention. For example, the double-pipe heat exchanger-reactors may be positioned in a radiant furnace (not shown).

## Claims

1. Apparatus suitable for use in the production of synthesis gas from hydrocarbons which comprises a primary reforming zone in which a hydrocarbon - containing gas and steam are partially reformed in the presence of a primary reforming catalyst to produce a primary reformer effluent and a secondary reforming zone in which the primary reformer effluent and an oxygen - containing gas are reacted in the presence of a secondary reforming catalyst to produce a secondary reformer effluent characterised in that (1) the primary reforming zone comprises a plurality of double pipe heat exchanger - reactors arranged peripherally about the circumference of a single reforming zone and close coupled thereto and (2) each double pipe heat exchanger-reactor is (a) adapted to contain the primary reforming catalyst in either its central core or annulus and (b) provided with at least one inlet for introducing steam and hydrocarbon-containing gas into whichever of the central core or annulus contains the primary reforming catalyst, an outlet for conveying the primary reformer effluent to the secondary reforming zone and an inlet for

introducing the secondary reformer effluent into whichever of the central core or annulus does not contain the primary steam reforming catalyst countercurrently to the steam and hydrocarbon-containing gas and an exit from the same for removing the secondary reformer effluent from the apparatus.

2. Apparatus as claimed in claim 1 wherein each double pipe heat exchanger-reactor is adapted to contain primary reforming catalyst in its annulus.
3. Apparatus as claimed in claim 1 characterised in that the secondary reforming zone is cylindrical and has a diameter which is large relative to that of each double-pipe heat exchanger-reactor.
4. Apparatus as claimed in claim 1 further comprising a guard bed connected to the upstream side of each inlet for introducing the hydrocarbon-containing gas.
5. Apparatus as claimed in claim 1 characterised in that each double-pipe heat exchanger-reactor is provided with a packed stuffing box.
6. Apparatus as claimed in claim 1 further comprising a means for preheating the hydrocarbon-containing gas and the steam.
7. Apparatus as claimed in claim 1 characterised in that each double pipe heat exchanger-reactor is adapted so that whichever of the central core or annulus is not adapted to contain the primary reforming catalyst is adapted to contain a carbon monoxide shift catalyst.
8. Apparatus as claimed in claim 1 characterised in that the secondary reforming zone is a refractory lined reactor adapted to operate under essentially adiabatic conditions.
9. Apparatus as claimed in claim 8 wherein the refractory lined reactor is four meters in diameter as is surrounded by twelve double pipe heater-exchanger reactors.
10. A process for producing a secondary reformer effluent comprising synthesis gas from a hydrocarbon-containing gas which comprises the steps of
  - (1) charging an apparatus as defined in any one of claims 1 to 9 with a primary reforming catalyst, a secondary reforming catalyst and optionally a carbon monoxide shift catalyst

(2) feeding the hydrocarbon-containing gas and steam to each double pipe exchanger-reactor

(3) feeding an oxygen-containing gas to the secondary reforming zone, and

(4) removing the secondary reformer effluent from the apparatus via the exit on each double-pipe heat exchanger-reactor.

## Revendications

1. Appareil apte à être utilisé dans la production de gaz de synthèse à partir d'hydrocarbures, qui comprend une zone de reformage primaire dans laquelle un gaz contenant un hydrocarbure et de la vapeur d'eau sont partiellement reformés en présence d'un catalyseur de reformage primaire pour produire un effluent de l'appareil de reformage primaire et une zone de reformage secondaire dans laquelle l'effluent de l'appareil de reformage primaire et un gaz contenant de l'oxygène sont amenés à réagir en présence d'un catalyseur de reformage secondaire pour produire un effluent d'appareil de reformage secondaire, caractérisé en ce que (1) la zone de reformage primaire comprend une pluralité de réacteurs-échangeurs de chaleur à double tube à agencement périphérique autour de la circonférence d'une zone unique de reformage et en couplage étroit avec elle et (2) chaque réacteur-échangeur de chaleur à double tube est (a) conçu pour contenir le catalyseur de reformage primaire dans son noyau central ou espace annulaire et (b) équipé d'au moins un conduit d'admission pour l'introduction de vapeur d'eau et de gaz contenant des hydrocarbures dans tout noyau central ou espace annulaire qui contient le catalyseur de reformage primaire, d'un conduit de sortie pour transporter l'effluent de l'appareil de reformage primaire dans la zone de reformage secondaire et d'un conduit d'admission servant à introduire l'effluent de l'appareil de reformage secondaire dans n'importe quel noyau central ou espace annulaire qui ne contient pas le catalyseur de reformage primaire à la vapeur, à contre-courant avec la vapeur et le gaz contenant les hydrocarbures et une sortie pour décharger de l'appareil l'effluent de l'appareil de reformage secondaire.
2. Appareil suivant la revendication 1, dans lequel chaque réacteur-échangeur de chaleur à tube double est conçu pour contenir dans son espace annulaire du catalyseur primaire de reformage.
3. Appareil suivant la revendication 1, caractérisé

en ce que la zone de reformage secondaire est cylindrique et a un diamètre qui est grand par rapport à celui du réacteur échangeur de chaleur à double tube.

4. Appareil suivant la revendication 1, comprenant en outre un lit de protection relié au côté amont de chaque tube d'admission pour l'introduction de gaz contenant un hydrocarbure.
5. Appareil suivant la revendication 1, caractérisé en ce que chaque réacteur-échangeur de chaleur à double tube est pourvu d'un presse-étoupe garni.
6. Appareil suivant la revendication 1, comprenant en outre des moyens de préchauffage du gaz contenant un hydrocarbure et de la vapeur.
7. Appareil suivant la revendication 1, caractérisé en ce que chaque réacteur-échangeur de chaleur à double tube est réalisé de manière que le noyau central ou l'espace annulaire qui n'est pas adapté pour contenir le catalyseur de reformage primaire soit conçu pour contenir un catalyseur de conversion de l'oxyde de carbone.
8. Appareil suivant la revendication 1, caractérisé en ce que la zone de reformage secondaire est un réacteur à garniture réfractaire conçu pour fonctionner dans des conditions essentiellement adiabatiques.
9. Appareil suivant la revendication 8, dans lequel le réacteur à garniture réfractaire a un diamètre de quatre mètres et est entouré de douze réacteurs-échangeurs de chaleur à double tube.
10. Procédé de production d'un effluent de reformeur secondaire comprenant du gaz de synthèse à partir d'un gaz contenant un hydrocarbure, qui comprend les étapes consistant :
  - (1) à charger un appareil tel que défini dans l'une quelconque des revendications 1 à 9 avec un catalyseur de reformage primaire, un catalyseur de reformage secondaire et, à titre facultatif, un catalyseur de conversion d'oxyde de carbone
  - (2) à faire arriver le gaz contenant un hydrocarbure et de la vapeur d'eau dans chaque réacteur-échangeur à double tube
  - (3) à charger un gaz contenant de l'oxygène dans la zone de reformage secondaire et
  - (4) à évacuer l'effluent du reformeur secondaire de l'appareil par la sortie prévue sur

chaque réacteur-échangeur de chaleur à double tube.

#### Patentansprüche

1. Vorrichtung, die zur Verwendung bei der Herstellung von Synthesegas aus Kohlenwasserstoffen geeignet ist, umfassend eine erste Reformierungszone, in der ein Kohlenwasserstoff-enthaltendes Gas und Dampf in Anwesenheit eines ersten Reformierungskatalysators teilweise reformiert werden, um einen ersten Reformierungsabfluß zu bilden und eine zweite Reformierungszone, in der der erste Reformierungsabfluß und ein Sauerstoff-enthaltendes Gas in Anwesenheit eines zweiten Reformierungskatalysators umgesetzt werden, um einen zweiten Reformierungsabfluß zu bilden, dadurch gekennzeichnet, daß (1) die erste Reformierungszone eine Vielzahl von Doppelrohrwärmeaustausch-Reaktoren umfaßt, die peripherisch um den Umkreis einer einzelnen Reformierungszone angeordnet und fest damit verbunden sind und (2) jeder Doppelrohrwärmeaustausch-Reaktor (a) dazu geeignet ist, den ersten Reformierungskatalysator entweder in seinem zentralen Kern oder Ringraum zu enthalten und (b) mit wenigstens einer Eintrittsöffnung zum Einführen von Dampf und Kohlenwasserstoff-enthaltendem Gas in den zentralen Kern oder den Ringraum, in Abhängigkeit davon, welcher den ersten Reformierungskatalysator enthält, einer Austrittsöffnung zum Zuführen des ersten Reformierungsabflusses zu der zweiten Reformierungszone und einer Eintrittsöffnung zum Einführen des zweiten Reformierungsabflusses in den zentralen Kern oder den Ringraum, in Abhängigkeit davon, welcher den ersten Dampf-Reformierungskatalysator nicht enthält, gegenströmig zu dem Dampf und Kohlenwasserstoff-enthaltenden Gas und einem Ausgang aus diesem, um den zweiten Reformierungsabfluß aus der Vorrichtung auszuleiten, versehen ist.
2. Vorrichtung nach Anspruch 1, worin jeder Doppelrohrwärmeaustausch-Katalysator dazu geeignet ist, den ersten Reformierungskatalysator in seinem Ringraum zu enthalten.
3. Vorrichtung nach Anspruch 1, dadurch gekennzeichnet, daß die zweite Reformierungszone zylindrisch ist und einen im Verhältnis zu jedem Doppelrohrwärmeaustausch-Reaktor großen Durchmesser aufweist.
4. Vorrichtung nach Anspruch 1, die weiterhin ein Schutzbett umfaßt, das mit der in Strömungs-

richtung oben gelegenen Seite jeder Eintrittsöffnung zum Einführen des Kohlenwasserstoff-enthaltenden Gases verbunden ist.

5. Vorrichtung nach Anspruch 1, dadurch gekennzeichnet, daß jeder Doppelrohrwärmeaustausch-Reaktor mit einer gepackten Stopfbüchse versehen ist.
6. Vorrichtung nach Anspruch 1, die weiterhin ein Mittel zum Vorwärmen des Kohlenwasserstoff-enthaltenden Gases und Dampfs umfaßt.
7. Vorrichtung nach Anspruch 1, dadurch gekennzeichnet, daß jeder Doppelrohrwärmeaustausch-Reaktor derart beschaffen ist, daß der zentrale Kern oder Ringraum, der nicht dazu vorgesehen ist den ersten Reformierungskatalysator zu enthalten, dazu vorgesehen ist einen Kohlenmonoxid-Konvertierungskatalysator zu enthalten.
8. Vorrichtung nach Anspruch 1, dadurch gekennzeichnet, daß die zweite Reformierungszone ein feuerfest ausgekleideter Reaktor ist, der dazu geeignet ist, unter im wesentlichen adiabatischen Bedingungen zu arbeiten.
9. Vorrichtung nach Anspruch 8, worin der feuerfest ausgekleidete Reaktor einen Durchmesser von 4 Metern aufweist und von 12 Doppelrohrwärmeaustausch-Reaktoren umgeben ist.
10. Verfahren zur Herstellung eines zweiten Reformierungsabflusses umfassend Synthesegas aus einem Kohlenwasserstoff-enthaltenden Gases, das die folgenden Schritte umfaßt:
  - (1) Füllen einer Vorrichtung wie einem der Ansprüche 1 bis 9 definiert, mit einem ersten Reformierungskatalysator, einem zweiten Reformierungskatalysator und gegebenenfalls einem Kohlenmonoxid-Konvertierungskatalysator
  - (2) Einführen des Kohlenwasserstoff-enthaltenden Gases und Dampfs in jeden Doppelrohrwärmeaustausch-Reaktor
  - (3) Einführen eines Sauerstoff-enthaltenden Gases in die zweite Reformierungszone und
  - (4) Ausleiten des zweiten Reformierungsabflusses aus der Vorrichtung über den Ausgang an jedem Doppelrohrwärmeaustausch-Reaktor.



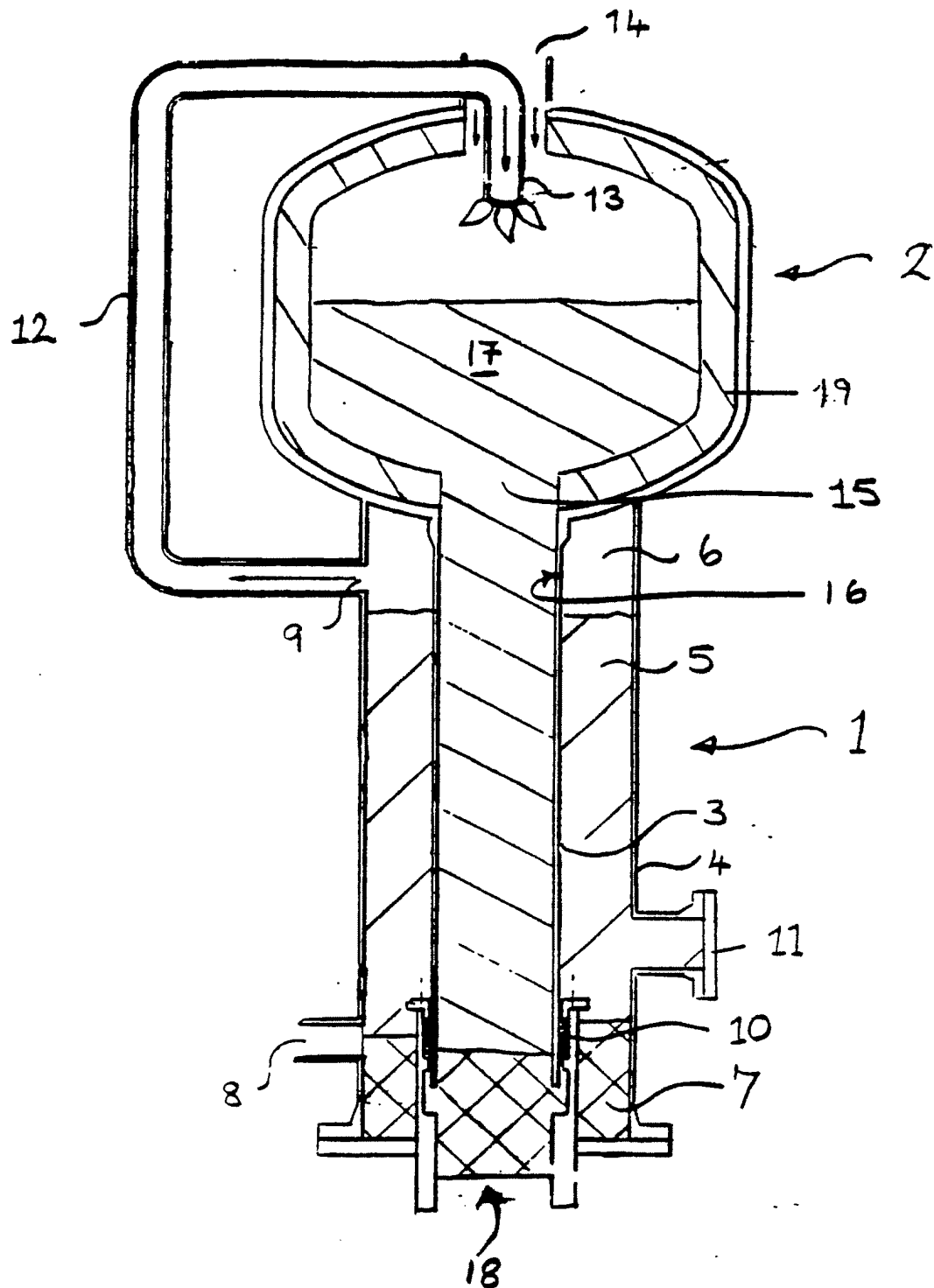


FIG 7

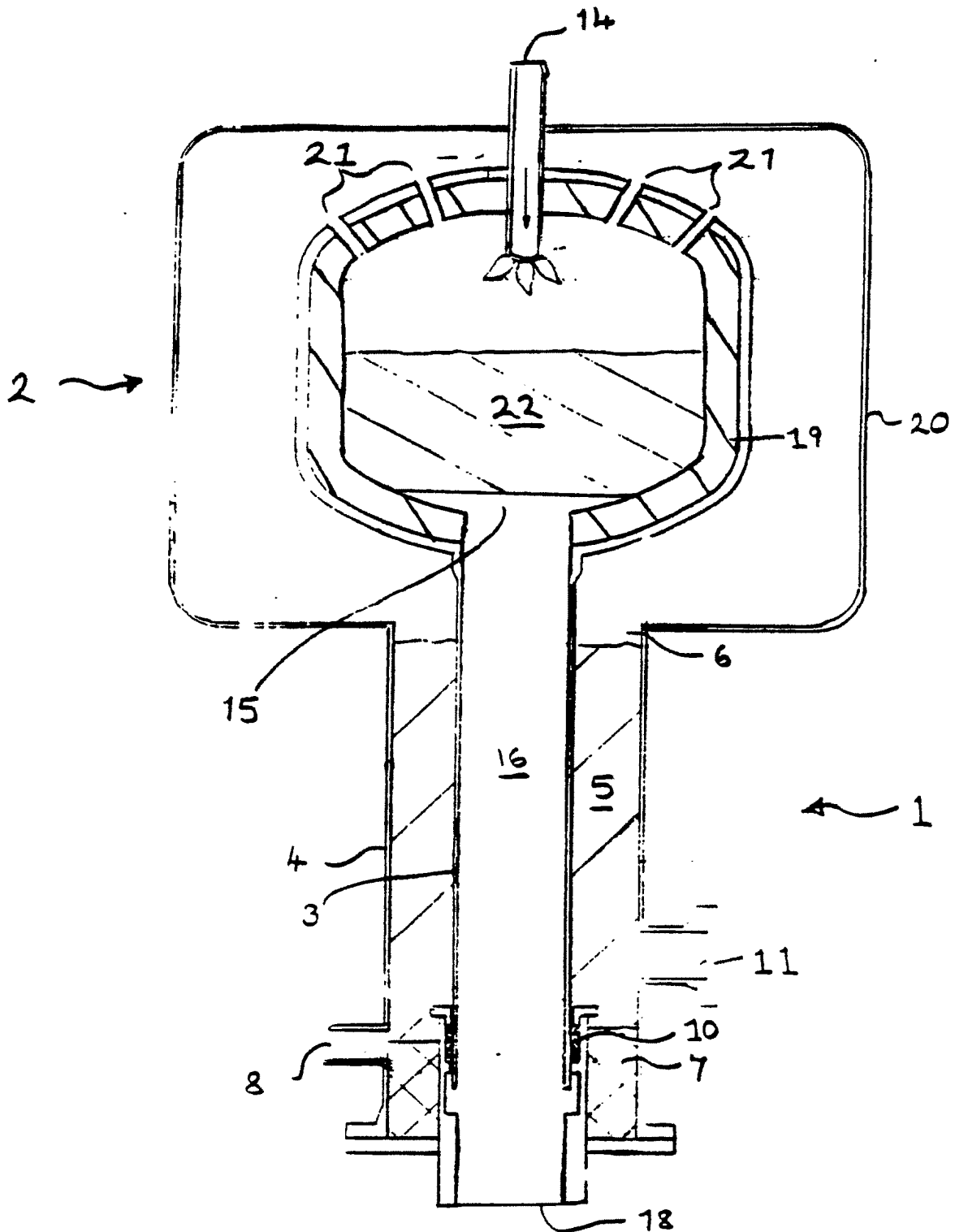


FIG. 2

Figure 3

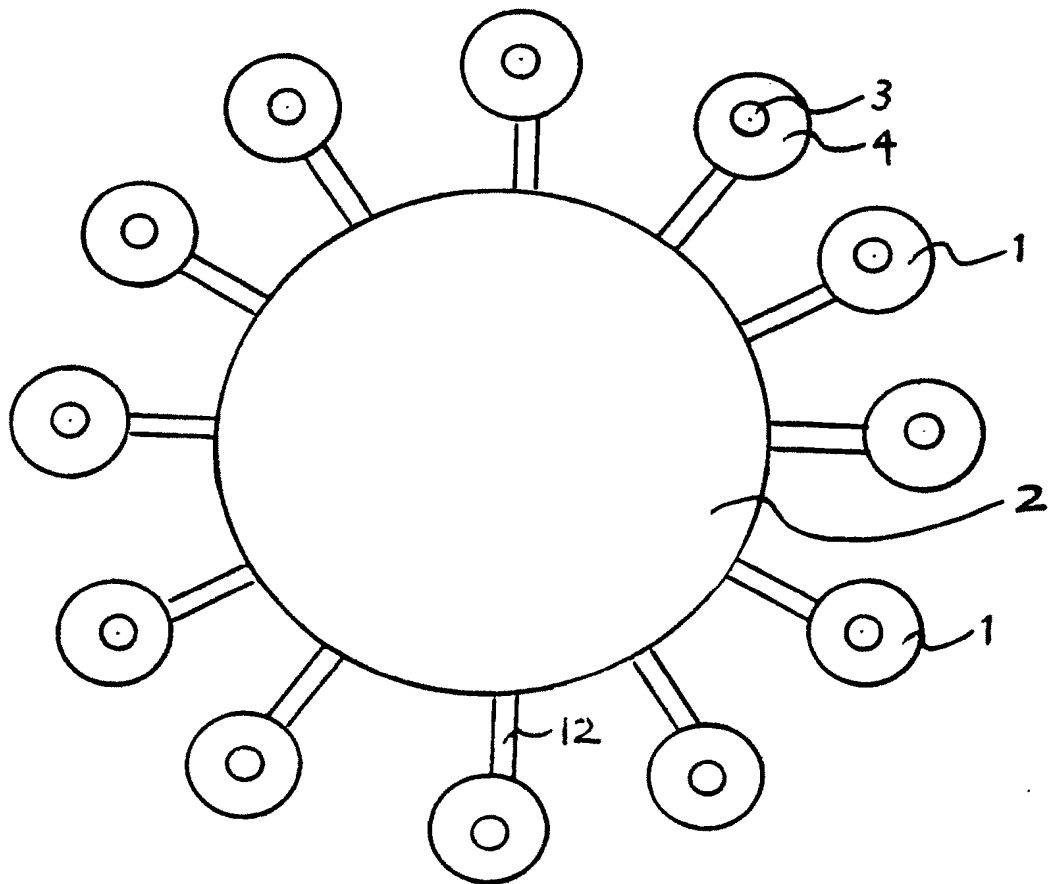


Fig. 4

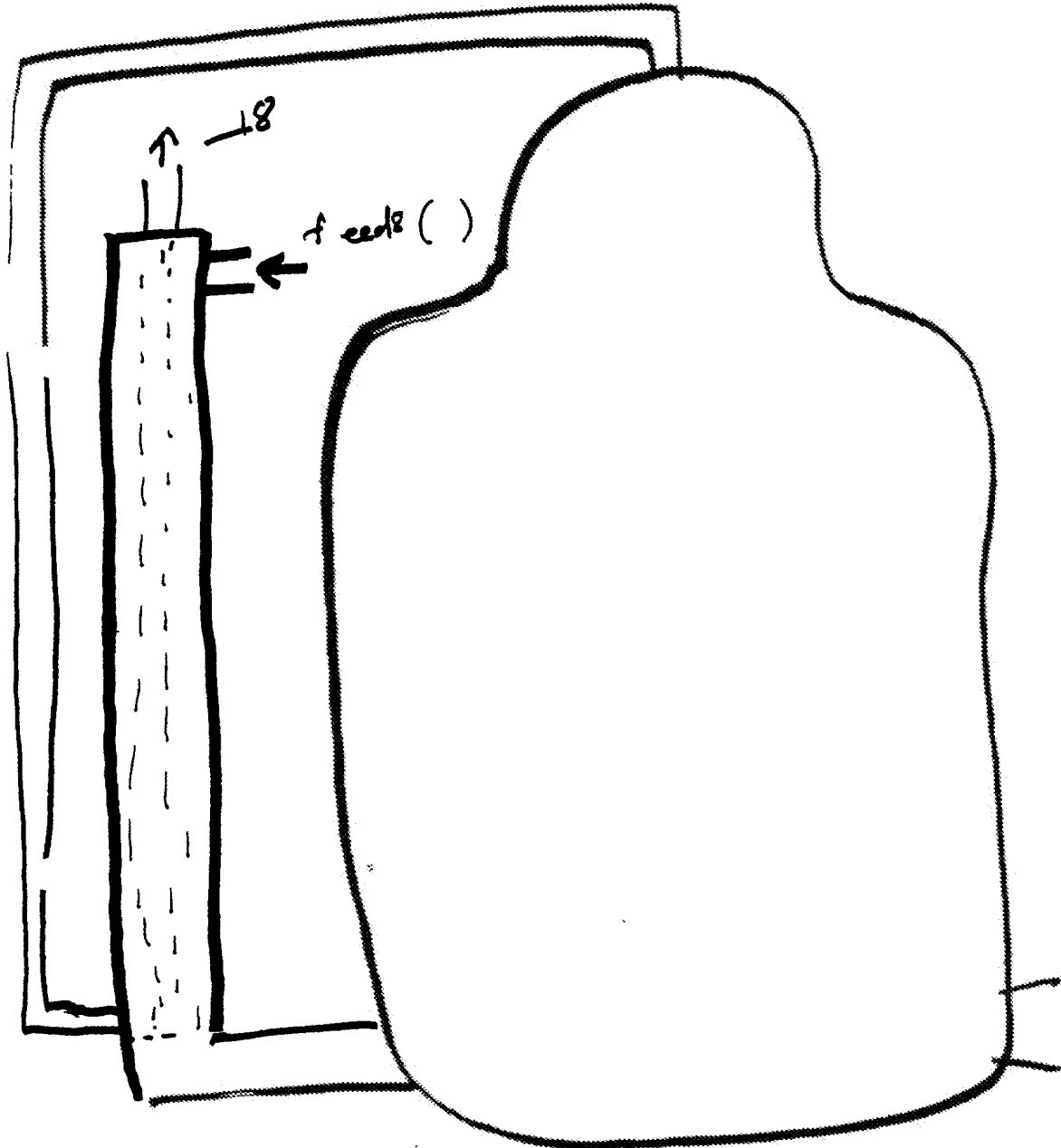


FIGURE 5

